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Fuzzy Logic for the Estimation of Global Solar Radiation in South India

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ABSTRACT:-Forecasting global solar radiation of a location through fuzzy logic led to expect an improvement in the prediction of accuracy in the absence of measured solar radiation. A fuzzy system consists of a chart between input (premises) and output (conclusions) represented by IF-THEN rules. Hence, an attempt has been made to propose fuzzy logic for forecasting global solar radiation at Chennai, Trivandrum and Visakhapatnam. Efforts have also been devoted to the integration of certain meteorological parameters in the fuzzy algorithm aiming to increase accuracy.

KEYWORDS: -Solar Energy, Solar Radiation, Fuzzy Logic, Fuzzy Rule

I. INTRODUCTION

Rapid urbanization and increase of population have to the demand for considering various energy sources to produce electricity. As the requirement of electricity increases exponentially, the depletion of fossil fuel reserves is also increasing proportionally, leading to the emission of large amount of greenhouse gases. Hence it is highly desirable to spot and depend on energy sources which are renewable and non-conventional. One of the most promising renewable energy sources is the solar energy, which is available, free of cost and is also environmental friendly. Since India lies on the equatorial Sun Belt and also intercepts solar radiation of about 300 solar days it contains a huge potential of Solar energy per year, The estimation of solar radiation in various places of the country is indispensable Rizwan (2010), Ahmed (2009) and Gupta (2011). Researchers all over the world have been making sincere efforts to propose various regression and stochastic models for estimating of solar radiation in clear sunny days Rizwan (2010), Kaplanin (2010), Kaplanin (2007), Kaplanin (2006) and Falayi (2008) and these models are not found to be suitable for cloudy days. In order to overcome the inconvenience in the existing models, researchers have taken sincere efforts to propose fuzzy logic based models to estimate the solar energy at a location utilizing different meteorological parameters. In 1965, Ghosh (2006) introduced fuzzy set theory with multivalued logic allowing the intermediate values between the extreme maximumand minimum values under consideration. Sen (1998) proposed a fuzzy logic algorithm for estimating solar radiation from sunshine duration measurements. Further meteorological parameters such as air temperature, relative humidity and sunshine duration were used by Alata (2005) to propose a fuzzy logic model for the calculating of global solar radiation on a horizontal surface. Bhardwaj (2013) was incorporated cloudiness index to propose a model for the estimation of global solar radition using fuzzy random variables and succeeded. Fuzzy logic procedure was used for the computation of solar irradiation on arbitrarily oriented surfaces by Gomez &Casanovas (2013) who validated the model. In the present work, an attempt has been made to derive a set of fuzzy rules to relate solar irradiation and sunshine duration measurements in Chennai, Trivandrum and Visakhapatnam. The proposed fuzzy logic algorithm has been used to estimate the solar radiation from sunshine duration. Fuzzy ruled can be used instead of regression equations for the evaluating of solar radiation in Chennai, Trivandrum and Visakhapatnam.

II. FUZZY LOGIC

A fuzzy engine, as per figure 1, is typified by the inference system that includes the system rule base, input membership functions that fuzzify the input variables and the output variable de-fuzzification process. Fuzzification is a procedure where crisp input values are represented in terms of the membership function, of the fuzzy sets. The fuzzy logic controller triangular membership functions are defined over the range of the fuzzy input values and linguistically describe the variable's universe of discourse as shown in figure 2.

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Following the fuzzification process the inference engine determines the fuzzy output using fuzzy rules that are in the form of if then rules. De-fuzzification is then used to translate the fuzzy output to a crisp value.
It is proposed here that the metrics link strength, energy available at a link vertex, and number of hops in a path will be combined into a single decision thereby optimizing a routing protocol over a number of metrics and making it more robust.

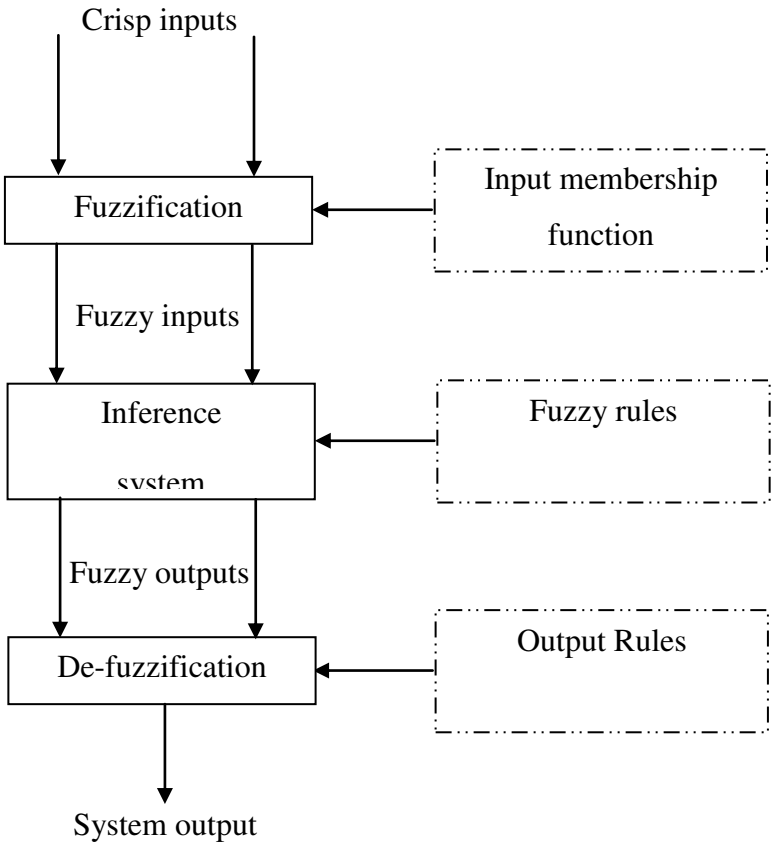

Figure 1: Fuzzy Logic System

Sensor nodes with medium power, high memory and high processing speed can be used for event monitoring.

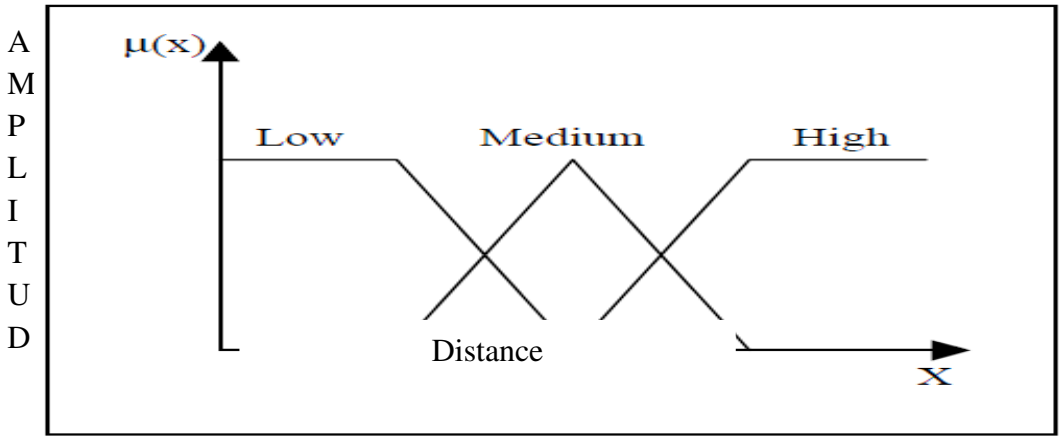

Figure 2: Fuzzy Logic membership Function

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Sensor nodes with medium power and low memory and processing speed can be used for critical monitoring. Sensor nodes with low power and low memory and low processing speed cannot be used for monitoring.
The decision to continue with a network broadcast will be determined via a fuzzy logic system with the caching parameters being applied to a fuzzifier that translates them into fuzzy sets.

III. FUZZY RULE BASED ESTIMATION OF GLOBAL SOLAR RADIATION

Fuzzy rule based reasoning system consists of three components which would perform a specific task in the reasoning process i.e. fuzzification process, inferencing and defuzzification. The fuzzification process predicts a fuzzy representation of non-fuzzy input values by applying the membership functions associated with each fuzzy set in the rule input space. The process of mapping the fuzzified inputs into the rule base and to provide a fuzzified output to each rule is known as inferencing. Defuzzification process converts the output of the fuzzy rules into a scalar or non-fuzzy value. Mamdhani model has been utilized for this study and a description of the structure of these model follows

Mamdhani model is implemented by following the indispensable six steps given below
1. Determining a set of fuzzy rules
2. Fuzzifying the inputs using the input membership functions,
3. Combining the fuzzified inputs according to the fuzzy rules to establish a rule strength,
4. Finding the consequence of the rule by combining the rule strength and the output membership function,
5. Combining the consequences to get an output distribution, and
6. Defuzzifying the output distribution (this step is only if a crisp output (class) is needed).

Creating fuzzy rules
Fuzzy rules are a collection of linguistic statements that describe how the Fuzzy Inference System should make a decision regarding classifying an input or controlling an output. Fuzzy rules are always written in the following form: if (input1 is membership function1) and/or (input2 is membership function2) and/or then (output is output membership function).

Fuzzification
The purpose of fuzzification is to map inputs from a set of sensors (or features of those sensors such as amplitude or spectrum) to values ranging from 0 to 1 using a set of input membership functions. These inputs are mapped into fuzzy numbers by drawing a line up from the inputs to the input membership functions above and by marking the intersection point , Theseinput membership functions, can represent fuzzy concepts such as "large" or "small", "old" or "young", "hot" or "cold", etc. For example, x0 could be the EMG energy emanating from the front of the forearm and y0 could be the EMG energy emanating from the back of the forearm. The membership functions could then represent "large" amounts of tension released from a muscle or "small" amounts of tension. While choosing the input membership functions, the definition of what we mean by "large" and "small" may be different for each input.

Membership Functions
Three dynamic variables namely, global Solar radiation, ambient temperature and sunshine duration have been considered for the present study. Global solar radiation can be correlated with bright hours of sunshine and ambient temperature in the three locations Chennai, Trivandrum and Visakhapatnam to propose fuzzy rules. Hence, the three variables have been treated as the dynamic ones and considered as a fuzzy system and fuzzy logichas been proposed to that system. From the measured global solar radiation, over a period of time, the ambient temperature, number of bright hours of sunshine, the observed range of solar radiation, ambient temperature and duration of sunshine have been found. Based on these ranges of experimental results, the patterns of membership functions for the three variables have been generated for Chennai, Trivandrum and Visakhapatnam. Membership functions have been determined by proposing different weightage for the three dynamic variables. Figures (3-6) present the patterns obtained for the three dynamic variables in Chennai, Trivandrum and Visakhapatnam.

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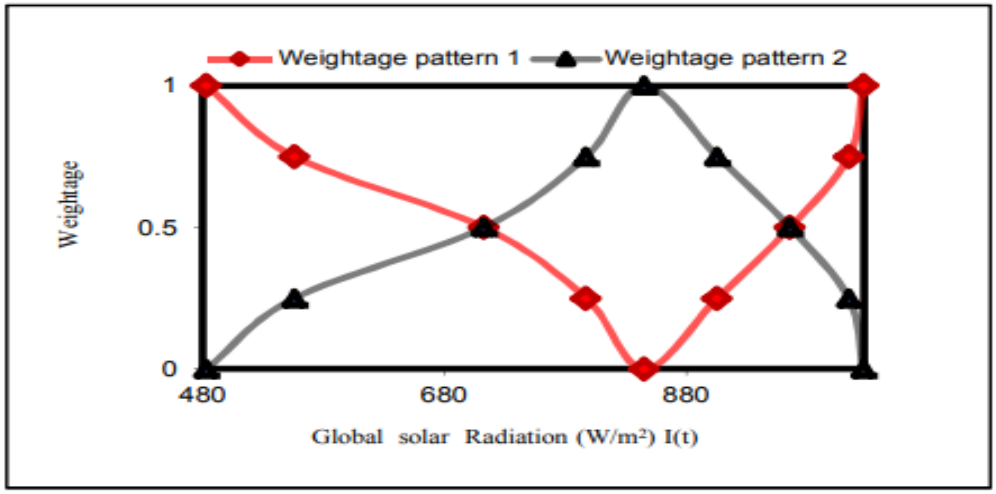

Figure 3: Pattern for variation of global solar radiation in Chennai

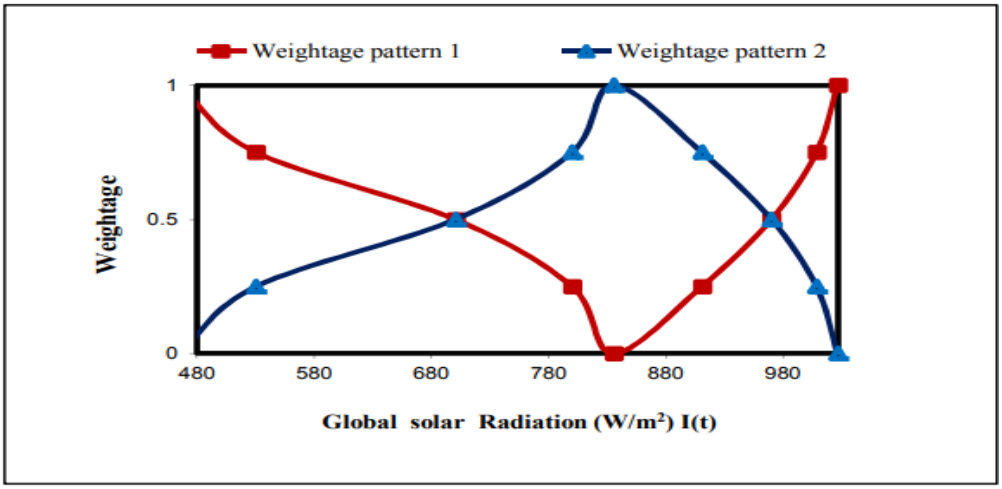

Figure 4: Pattern for variation of global solar radiation in Trivandrum

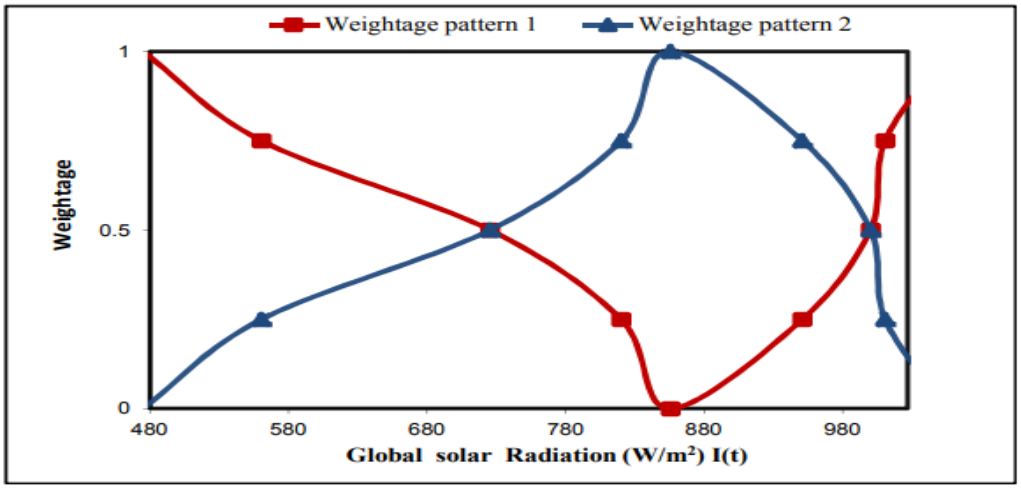

Figure 5: Pattern for variation of global solar radiation in Visakhapatnam

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IV. METHODOLOGY

Generalized Fuzzy rules have been framed for Chennai, Trivandrum and Visakhapatnam Since the all three locations are coastal areas displaying the same trend of variation of global solar radiation, generalized Fuzzy rules have been framed for Chennai, Trivandrum and Vishakhapatnam. This would enable various results.

Rule 1: IF (Sunshine duration is High) AND (Ambient Temperature is Low), THEN (Global Solar radiation is Low).
Rule 2: IF (Sunshine duration is High) AND (Ambient Temperature is Normal), THEN (Global Solar radiation is Normal).
Rule 3: IF (Sunshine duration is Normal) AND (Ambient Temperature is Low), THEN (Global Solar radiation is Normal).
Rule 4: IF (Sunshine duration is Normal) AND (Ambient Temperature is Normal), THEN (Global Solar radiation is Normal).
Rule 5: IF (Sunshine duration is High) AND (Ambient Temperature is High), THEN (Global Solar radiation is High).
Rule 6: IF (Sunshine duration is Normal) AND (Ambient Temperature is High), THEN (Global Solar radiation is Low).
Rule 7: IF (Sunshine duration is Low) AND (Ambient Temperature is Low), THEN (Global Solar radiation is Low).
Rule 8: IF (Sunshine duration is Low) AND (Ambient Temperature is Normal), THEN (Global Solar radiation is Low).
Rule 9: IF (Sunshine duration is Low) AND (Ambient Temperature is High), THEN (Global Solar radiation is Low).

V. SIMULATION RESULTS

To validate the proposed fuzzy rules, results obtained for global solar radiation at Chennai, Trivandrum and Visakhapatnam using fuzzy rules have been compared with the global solar radiation measured for one of the typical days in May. The Mamdhani model has been used to predict the global solar radiation. Table 1 presents the measured global solar radiation at Chennai, Trivandrum and Visakhapatnam along with the results obtained from the Mamdhani simulation model.

Table 1: Measured and Simulation results in W/m2

Chennai		Trivandrum		Visakhapatnam	
Measured Global Solar Radiation	Simulated global solar radiation	Measured Global Solar Radiation	Simulated global solar radiation	Measured Global Solar Radiation	Simulated global solar radiation
555	554.235	560	558.216	549	550.324
797	795.264	780	782.692	792	796.236
905	903.254	901	903.527	912	915.657
966	968.854	968	966.596	975	970.834
1026	1022.782	1020	1018.452	1026	1030.251
1014	1016.375	1008	1006.239	1020	1024.783
845	848.943	856	854.862	856	848.237
712	715.586	705	703.421	710	712.967
483	485.213	475	480.694	482	485.786

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For comparison purposes, the amount of the global solar radiation using different values of ambient temperature and bright hours of sunshine are in Table.1, along with the measured value for comparison purposes. From the results, three-dimensional graphs have been generated between the three variables and are depicted in Figures 6. The relative standard deviation between the measured global solar radiation has also been determined and fuzzy rule based simulation results are presented in order to signify the closeness of the trend. It can be observed that there is a reasonable agreement between the simulation and measured values of global solar radiation for all the three locations. In all the three cases, the minimum and maximum relative standard deviation between the measured and estimated global solar radiation for the three locations can be found to be less than 7% ,on an average.

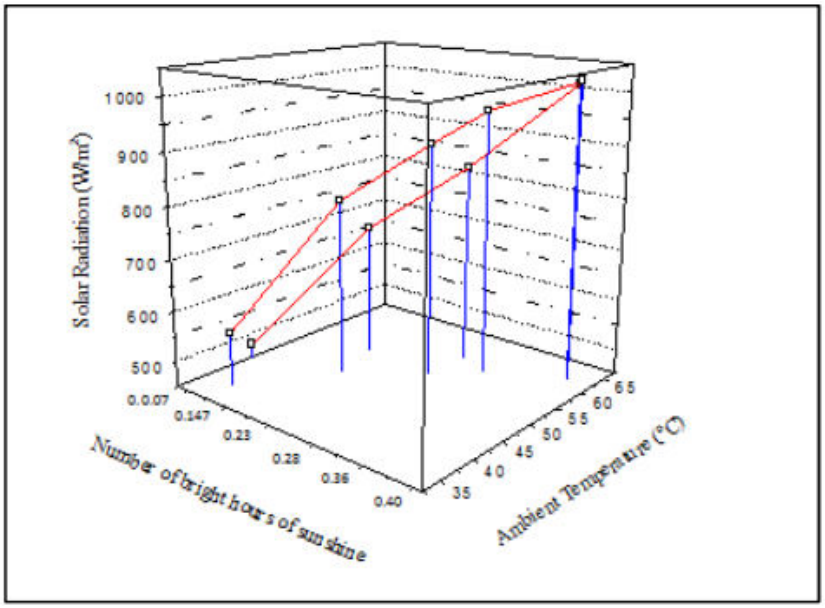

Figure 6: Three-dimensional graphs between global solar radiation, ambient temperature and number of bright hours of sunshine in Chennai

VI. CONCLUSION

The concept of fuzzy logic modeling of global solar radiation in Chennai, Trivandrum and Visakhapatnam and the results pertaining to the theory is quite impressive. It not only provide a meaningful and powerful representation of measuring uncertainties, but also a meaningful representation of vague concepts expressed in natural languages. Thus a fuzzy model of the system can be defined mathematically by assigning to each possible individual a value representing its grade of membership in the fuzzy set. This grade corresponds to the degree to which its individual is similar or compatible with the concept. These results provide enormous scope for the applications of the developed fuzzy system in estimating of global solar radiation.

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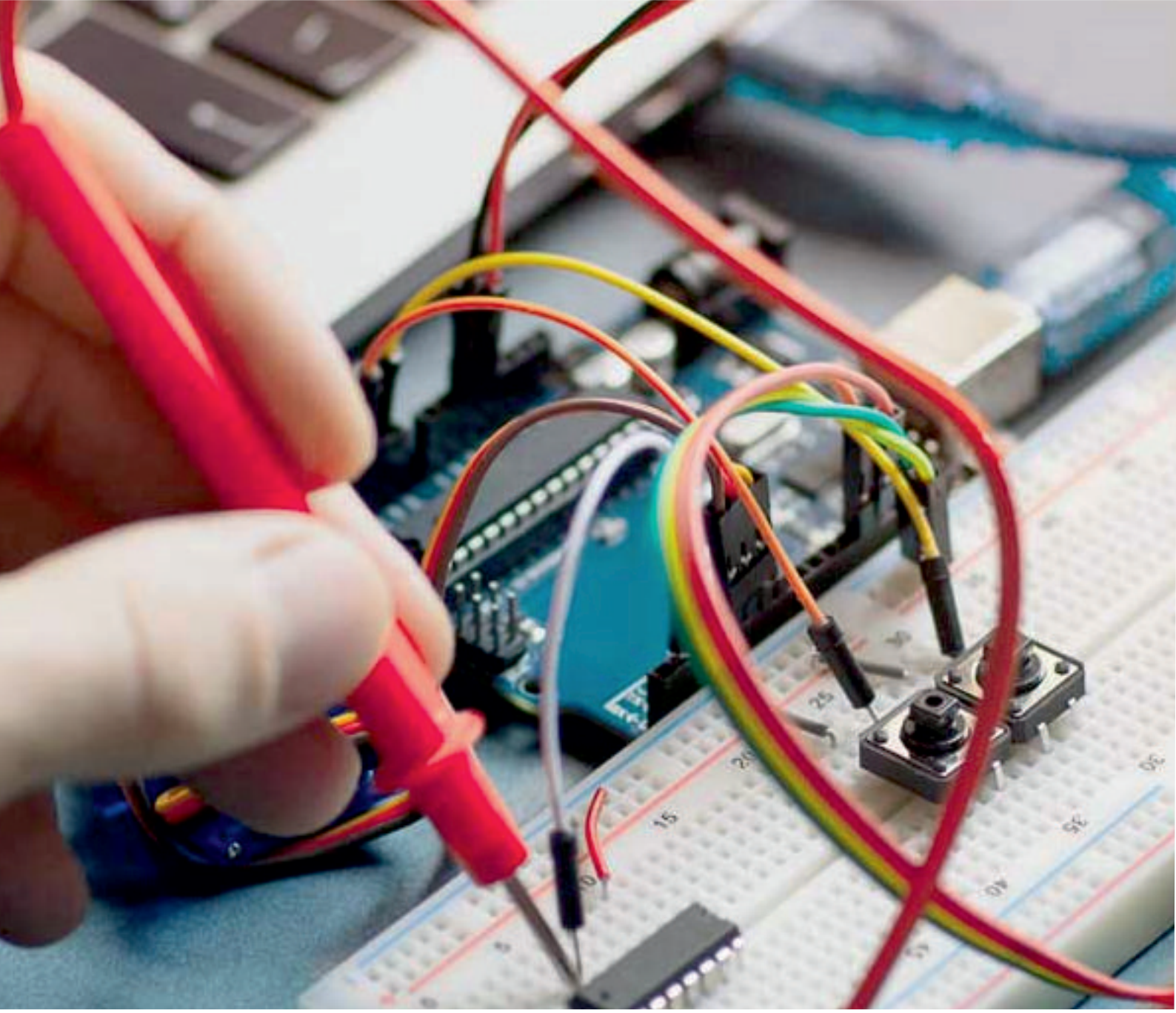

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